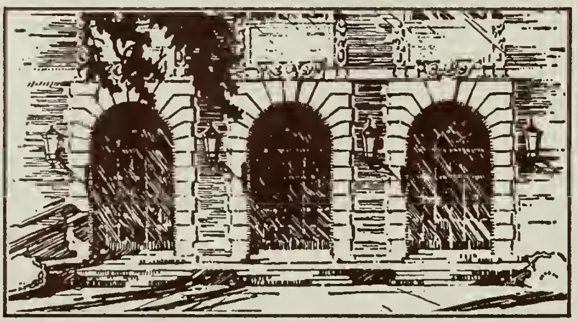

DCS Report No. 431

ILLIAC IV
QUARTERLY PROGRESS REPORT

October, November, and December 1970

Contract No.
USAF 30(602)-4144

ILLIAC IV Document No. 238

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN · URBANA, ILLINOIS

ILLIAC IV

QUARTERLY PROGRESS REPORT

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Contract No.
USAF 30(602)-4144

Department of Computer Science
University of Illinois at Urbana-Champaign
Urbana, Illinois
61801

January 15, 1971

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REPORT SUMMARY

At the beginning of the quarter, diagnostics production and the diagnostics generator system was subcontracted to Automation Technology, Inc. of Champaign, Illinois.

The software effort was directed primarily towards preparing existing codes for the Burroughs B6500 computer, providing a coherent body of documentation for users and for reference purposes, and providing a COCKROACH (ILLIAC IV FORTRAN) to GLYPNIR translator. COCKROACH programs are now being compiled satisfactorily and work continues on extending the existing subset of FORTRAN.

During the quarter an interface to connect the PDP-11 System to an Interface Message Processor (IMP) was specified and designed. The PDP-11 simulator on the B5500 was completed.

Bids were received and final purchase orders sent for hardware items for the ARPA Network port facility for the Center for Advanced Computation. Delivery of the items is expected in January, 1971.

Negotiations were begun with Digital Equipment Corporation concerning a financial support agreement for the development of the ARPA Network port facility.

Negotiations on the final cost for the ILLIAC IV computer have been concluded. The result of the negotiations are that Burroughs Corporation has submitted an anticipated cost-to-complete of 27.7 million dollars. Amendment VI of the contract between the University of Illinois and Burroughs will reflect that the cost for the computer system will be 27 million dollars and that Burroughs and the Federal Government will enter into a cost sharing agreement up to 31 million dollars.

The contracts for the Laser Mass Memory System were signed in late December. Precision Instrument Company of Palo Alto, California has been contracted for this system which is to be attached to the ILLIAC IV computer system.

Project expenditures and commitments through December, 1970:

Burroughs Corporation	$26,296,116.00
University of Illinois	6,482,715.92

1. HARDWARE

1.1 Diagnostics

At the beginning of this quarter all responsibility for diagnostics production and the diagnostics generator system was subcontracted to Automation Technology, Inc. of Champaign, Illinois.

2. SOFTWARE

2.1 Operating System

2.1.1 Operating System I

During this quarter, Operating System I (OS1) was brought as far to completion as the B5500 would allow. Most of the modules have been run together and have been found to work. In the latter half of the quarter much of this work has been reproduced on the B6500. The possibility of simulating ILLIAC IV through its own operating system is being studied.

2.2 Compilers and Translators

2.2.1 GLYPNIR

GLYPNIR, Version II, was released and has been running well. Version II includes:

- I/O statements for the simulator;
- Vectors;
- Changes to some control statements (notably the <IF statement>).

Version II was also converted to run on the B6500. As of December 31, 1970 the compiler works correctly on the B6500 although the 6500 version will not be supported until the end of the first quarter of 1971.

2.2.2 COCKROACH

A program which translates the first version of a subset of ILLIAC IV COCKROACH (FORTRAN) into GLYPNIR was written using the TWST translator writing system.

Some minor modifications to the language specifications have been made to enhance translatability. Several benchmarks will now be written and tested.

2.3 Assembler

Work began on translating the simulator and assembler to the B6500, but this is proceeding relatively slowly because of the difficulty in accessing a B6500.

A collection of mathematical macros has been made, debugged and documented. These macros (such as inner (32 bit) to full (64 bit) precision conversion) together with trigonometric and elementary mathematical subroutine (SIN, COS, SQRT, etc.) will form an excellent basis for a library of functions available to programmers in ASK, GLYPNIR and COCKROACH; all are written in ASK.

2.4 Interactive Communications and Graphics

2.4.1 Interactive Communications

During the reporting period, several major software efforts for the PDP-11 system were started, completed or continued.

- The B5500 PDP-11 simulator was completed.
- A high-level language compiler, PEESPOL (runs on B5500), was completed as Version I.
- Ninety per cent of the coding to be done on the ARPA Network Terminal System (ANTS) has been done--50% debugged by simulation.
- A paper describing software development for the B6500 to IMP interface was completed.

Bids were received and final purchase orders sent for the following hardware items for the ARPA network port facility:

1 ea.	PDP-11/20-CA system
3 ea.	4k words memory
1 ea.	real time clock
1 ea.	high speed paper tape system
1 ea.	KSR-35 operators TTY
1 ea.	card reader
1 ea.	132 column line printer
1 ea.	256k word disk
2 ea.	DECtape drives
12 ea.	2400 baud line interfaces
2 ea.	150 baud line interfaces
4 ea.	103A dataset controls and interfaces
6 ea.	general purpose interfaces.

Delivery of these items is to begin in early January, 1971.

An interface to connect the PDP-11 to an IMP was completed and specified. Backplane wiring will be performed by Digital Equipment Corporation (DEC); DEC modules will also be used.

Bids were received on:

- Alphanumeric CRT's -- Four terminals have been ordered from Hazeltine. The terminals will operate at 2400 baud.
- A graphics storage scope terminal -- One terminal with a joy stick has been ordered from Computek.
- An electrostatic printer -- A Gould 4800 system is now on order from Automation Techology, Inc.

Negotiations were begun toward a financial support agreement with DEC on the development of the ARPA network port facility.

2.4.2 Graphics

Aside from the purchase of a storage scope terminal system, work continued in the area of contour presentation algorithms and surface function ($y = f(x,y)$) presentation systems.

2.5 Debugging Package

The debugging package, SPIDER, entered its initial implementation phase. While SPIDER is being implemented, the program DEVIL/BUGS is available for debugging through the SSK simulator on the B5500 and B6500. University personnel using this program have been very pleased with it.

2.6 B5500/B6500 Operations

Throughput on the B5500 was very good during the quarter, although a few days were lost because of air conditioning problems.

The Burroughs B6500 computer is expected to arrive at the University by the end of January, 1971. Ideally, the system will be operational by the end of February. It is expected that the B5500 will be maintained for one month following the installation of the B6500.

2.7 Software Documentation

A tour to some potential ILLIAC IV users and a user questionnaire have helped us gain insight into the service and performance users will expect of ILLIAC IV software.

An ILLIAC IV Software Reference Manual [1] has been set up, and provides a basis for a systematic system of documentation, a considerable amount of which was provided during the quarter.

3. APPLICATIONS

3.1 Numerical Analysis

3.1.1 Matrix Inversion and Solution of Linear Algebraic Equations

This quarter, the Householder triangularization subroutine for matrices less than 64 x 64 was completed and is executing correctly on the simulator. This routine has been standardized according to subroutine linkage prescribed in the software reference manual [1]. The Householder method allows the user to perform several matrix operations, including finding the inverse and solving a system of simultaneous linear equations. An iterative improvement of these operations is also allowed. Documentation for the user application is being completed.

Applying the Householder subroutine to several ill-conditioned test matrices revealed that double precision arithmetic is required for results of high accuracy, especially for large order matrices. Presently code is being written for the general size matrix in single precision and provisions are to be included for disk access of the matrices. The precision routines for addition, subtraction, multiplication, and division written by Toshio Yasui [2] are being tested for usage within the Householder subroutine for the general matrix. The main effort now is the internal computation and "checking out" the particular storage scheme to be used for high order matrices.

In addition to standardizing Householder subroutine linkage, the method of modification for matrix inversion was updated to comply with these standards; documentation is being completed for this method.

3.1.2 Eigenvalue Problems

3.1.2.1 Jacobi's Algorithm

Jacobi's algorithm for finding eigenvalues of real symmetric matrices has been written, debugged, tested successfully on the simulator, and documented.

The Jacobi algorithm has been modified to accept real normal matrices and return complex eigenvalues and complex eigenvectors. This modification has not been tested.

3.1.2.2 Eberlein's Algorithm

This algorithm has been coded and debugged. It is presently being tested for different matrices. During these tests further investigations for convergence and overcoming oscillation problems were conducted (see [6]). The problems arising have been solved; the solution is as follows:

In normalizing a real matrix the main concern is to maximize $C_{2k-1,2k}$, the off-diagonal elements of the matrix $C = A \otimes A^T - A^T \otimes A$. This is accomplished by applying orthogonal transformation matrices to C (see [6]). With these transformation matrices, the new $C_{2k-1,2k} \equiv C^1_{2k-1,2k}$ attains its maximum value, $C^1_{2k-1,2k} = 1/2\ h$, where

$$H = [4C^2_{2k-1,2k} + (C_{2k-1,2k-1} - C_{2k,2k})^2]^{1/2} \quad . \tag{1}$$

To maximize $C^1_{2k-1,2k}$, therefore, is to maximize $C^2_{2k-1,2k}$ <u>and</u>

$$(C_{2k-1,2k-1} - C_{2k,2k})^2 \quad .$$

So far the attention [6] has only been on maximizing $C_{2k-1,2k}$.

In order to maximize $C_{2k-1,2k-1} - C_{2k,2k}$, let us first look at an example:

Assuming the diagonal elements of C are of the form

$$\begin{bmatrix} \begin{pmatrix} -4 & \\ & 3 \end{pmatrix} & C_{1,2} \\ C^t_{1,2} & \begin{pmatrix} 0.5 & \\ & 0.5 \end{pmatrix} \end{bmatrix}$$

we see that $C_{33} - C_{44} = 0$ and it will not contribute to maximizing C'_{34}. The transformation matrix pertaining to this case will be an identity matrix and the element C_{34} will not change.

In exchanging row 2 and row 3 by means of an orthogonal transformation, C becomes

$$\begin{bmatrix} \begin{pmatrix} -4. & \\ & 0.5 \end{pmatrix} & \\ & \begin{pmatrix} 3. & \\ & 0.5 \end{pmatrix} \end{bmatrix}$$

and $C_{33} - C_{34} = 2.5$. Care must also be taken that the C_{ij} elements in the upper triangle of C are close to $\max_{i \neq j} |C_{ij}|$.

Tests have shown that taking both $C_{2k-1,2k}$, and $(C_{2k-1,2k-1} - C_{2k,2k})$ into account, oscillations are overcome, rate of convergence is faster, and the result (matrix normalization) is more accurate.

3.1.3 Roots of Polynomials

Newton's Method for evaluating square roots and solving non-linear systems of equations has been coded in ALGOL and debugged. The method for evaluating square roots has also been coded in ASK.

Work on Newton's Method in solving general polynomial equations has begun. Preliminary steps in the general root Finder include the use of the reciprocal polynomial for finding roots outside the unit circle. Algorithm applicability has not yet been decided for complex and multiple roots.

3.2 Linear Programming

Code development and testing have continued fairly smoothly this quarter. System flowcharts have been produced for the modified

Hellerman and Rarick reinversion algorithm for INVERT. ILLIAC IV assembly code (ASK) has been written for about 70% of the subroutines for this INVERT procedure. Testing of these codes will be initiated in the next quarter.

During this quarter the manpower assigned to LP has gradually been reduced to about one-half of the previous level. This has been accomplished by reassignment of LP personnel to other CAC projects and to increased responsibilities of LP personnel in other areas. This reduction is in keeping with the progress of the LP code and the schedule for further development. It is felt that the ASK programming and systems experience of LP personnel will be of value to other applications and software groups.

3.3 Long Codes

In an effort to improve on the results obtained with the previously developed system identification algorithms based on the stochastic approximation approach of R. C. K. Lee, the emphasis has been shifted to correlation techniques based on the work of Anderson, et al. [3], and Mehra [4].

Two identification schemes based on the work of Anderson, et al., have been implemented and are being tested. One algorithm, closely following the approach of reference [3], requires that the observation matrix, which relates the state vectors of the system to the observation vectors, must be an identity matrix. This scheme approximates the system transition matrix directly, thus requiring the determination of n^2 values. A second algorithm adapts this approach to the formulation used in the previously developed stochastic approximation procedures and determines an estimate for the n-vector, ψ, that represents the coefficients of the characteristic equation of the system transition matrix. This algorithm should give results comparable to the first algorithm while only determining n values instead of n^2 values.

Work with the correlation approaches indicates that it may be possible to extend them to obtain estimates for the covariance matrix of the observation noise. Since knowledge of the noise covariance matrix is extremely useful for identification or filtering, the possibility of determining observation noise covariance is appealing, and work is continuing in this direction.

3.4 Signal Processing

A GLYPNIR program has been written which computes the autocorrelation, c_i, of any given vector, X_i:

$$c_i = \sum_{j=0}^{N-i} X_{i+j} X_j, \qquad \text{where } i = 0, 1, 2, \ldots, N' \text{ and } N' \leq N.$$

This program is considerably slower than the corresponding ASK program [5], partly because GLYPNIR cannot access registers as efficiently or use the 32-bit mode.

A GLYPNIR subroutine is being written which will compute the fast Fourier transform of any real vector, f_j, of length $N = 64$. This subroutine gives the real and imaginary parts as well as the amplitude of the Fourier transform, g_j:

$$g_j = \sum_{k=0}^{N-1} f_k \exp(-2\pi ijk/N), \qquad j = 0, 1, 2, \ldots, N - 1.$$

This subroutine will be extended to cover any length which is a power of two between 64 and 4096, inclusive.

3.5 Education

3.5.1 ILLIAC IV Text

The initial version of the ILLIAC IV Textbook, "An Introductory Description of the ILLIAC IV System" will consist of three chapters--Background, Hardware Structure and Programming Languages--and will be

issued next quarter. Additional chapters will be issued at a later time.

3.5.2 ILLIAC IV Seminar

A one-day seminar on ILLIAC IV was held on November 3. The outline was basically the same as the outline noted in the previous QPR [6].

3.5.3 Computer Science-491B

The graduate course "Architecture, Applications and Languages for a Parallel Computer" will be offered again this Spring in Room 237 Digital Computer Laboratory on Monday, Wednesday, and Friday at 9 AM. The outline is, again, basically the same as the one presented in the last QPR.

4. ADMINISTRATION

4.1 Administration and Services

4.1.1 Contract Status

Negotiations on the final cost for the ILLIAC IV Computer have been concluded. Burroughs has submitted an anticipated cost to complete of 27.7 million dollars. The contract between the University of Illinois and Burroughs Corporation will reflect that the cost for the computer system will be $27 million and that Burroughs and the Federal Government will enter into a cost sharing agreement up to $31 million. The schedule for the cost sharing agreement is as follows:

Amount	Share Ratio Government/Burroughs
Up to $27,000,000	100% / 0%
$27,000,000 to $28,000,000	90% / 10%
$28,000,000 to $29,000,000	80% / 20%
$29,000,000 to $30,000,000	60% / 40%
$30,000,000 to $31,000,000	10% / 90%

The scheduled acceptance of the ILLIAC IV is June 1971. The Center for Advanced Computation is responsible for applications work and the ILLIAC IV Project is responsible for providing software for the ILLIAC IV.

During December, the prime contract between RADC and the University of Illinois for the Laser Mass Memory system was signed. The subcontract between the University of Illinois and Precision Instrument Company was also executed.

4.1.2 Financial Report

Budgeted expenditures--Second Quarter, Fiscal Year 1971:

	October	November	December	Total for Quarter
Burroughs	$1,747,936.00	$552,340.00	$793,811.00	$3,094,087.00
University	215,302.00	215,302.00	215,302.00	645,906.00

Actual expenditures and commitments--Second Quarter, Fiscal Year 1971 (through November, 1970):

	October	November	Total through November 1970
Burroughs	$1,104,216.00*	$296,000.00	$1,400,216.00
University	224,663.50	195,011.56	419,675.16

Total budgeted and actual expenditures to date:

	Total Budgeted Expenditures through December	Total Actual Expenditures through November
Burroughs Corporation	$26,296,116.00	$26,219,000.00
University of Illinois	6,482,715.92	6,266,182.95

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*Includes costs of ECS, Texas Instruments, and Fairchild as reflected in recent negotiations with Burroughs Corporation.

REFERENCES

[1] ILLIAC IV Computer System Software Reference Manual, ILLIAC IV Project, University of Illinois at Urbana-Champaign, Urbana, Illinois, (Fall 1970). (Currently for internal Project use only)

[2] Toshio Yasui, "Double Precision Arithmetic Routine for ILLIAC IV," ILLIAC IV Document No. 195, Department of Computer Science File No. 813, (October 8, 1969).

[3] W. N. Anderson, Jr., G. B. Kleindorfer, P. R. Kleindorfer, and M. B. Woodroofe, "Consistent Estimates of the Parameters of a Linear System," Annals of Mathematical Statistics, 40, No. 6, pp. 2064-2075, (1969).

[4] R. K. Mehra, "On-Line Identification of Linear Dynamic Systems with Applications to Kalman Filtering," Joint Conference on Mathematical and Computer Aid to Design, Anaheim, California, (October 1969).

[5] Steven S. Lai, "Correlation Analysis Program," ILLIAC IV Document No. 221, Department of Computer Science File No. 847, (June 15, 1970).

[6] ILLIAC IV Quarterly Progress Report, July, August, and September 1970. ILLIAC IV Document No. 236, Department of Computer Science Report No. 415, (October 15, 1970).

DOCUMENTS

Lawrie, Duncan H. "GLYPNIR: An Overview of the Language," ILLIAC IV Document No. 230, Department of Computer Science File No. 854, (August 19, 1970).

Lawrie, Duncan H. "GLYPNIR Programming Manual," ILLIAC IV Document No. 232, Department of Computer Science File No. 856, (August 27, 1970).

N. Abel, P. Kraska, T. Mason, and R. Trout, "Language Specifications for a FORTRAN-Like Higher Level Language for ILLIAC IV," ILLIAC IV Document No. 233, Department of Computer Science File No. 857, (August 28, 1970).

N. E. Abel and P. W. Kraska, "Extensions to FORTRAN for Array Processing," ILLIAC IV Document No. 235, Department of Computer Science File No. 859, (September 1, 1970).

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13. ABSTRACT

See the Report Summary on Page 1 within the Report itself.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Hardware Diagnostics						
Compilers and Generators						
GLYPNIR						
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Linear Programming						
Operating System I						
Assembler						
Education						
Signal Processing						
Matrix Algebra						
Ordinary and Partial Differential Equations						
Administration of Computing Centers						